Environmental Compatibility Research Workshop III
Existing NASA Program Overview

Monterey, California
July 7-9, 1998

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Environmental Emissions Level 1 Roadmap

FY00 FY02 FY07 FY17 FY22

Existing NASA Programs

Advanced Component Technologies for JP-Type Fueled A/C

- Propulsion
- Airframe
- Ground and Flight Operations

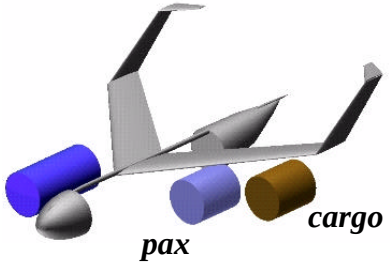
Phase 0 System Studies

TRL 6

Industry Develops & Certifies

10 Yr. Goal

25% CO2 & 67% NOx Reductions



Revolutionary Systems for Carbon-Based Fueled A/C

- Propulsion
- Airframe
- Assessment and Integration
- Ground and Flight Operations
- Alternate Fuel

- Ground Proof-of-Concept Test of Ultra Carbon-Based Engine

TRL 3-4

Revolutionary Carbon-Based Fueled Aircraft

- Flight Test of Adv. Engine Integrated on Box Wing Model

TRL 6

50% CO2 & 80% NOx Reductions

25 Yr. Goal

Industry Develops & Certifies

Revolutionary Concepts for Non-Carbon-Based Fueled A/C

Work Enabling Concepts/Technologies:

- Propulsion
- Airframe
- Alternate Fuel
- Integration and Ground Operations

Trl 2-3

Trl 3-4

- Ground Proof-of-Concept Test of Hydrogen Fuel Cell/Mini Fan

Revolutionary Zero-Emissions Aircraft

Enabling Concepts

Trl 3-4

- Flight Proof-of-Concept Test of Hydrogen Fuel Cell/Mini Fan on C-17

30-40 Yr. Goal

100% CO2 &100% NOx Reductions

Rational

- Atlanta Workshop suggested the identification of fundamental (practical and feasible) limits for conventional hydrocarbon fuels

- NASA System Studies had identified the Scenario-Based Vehicles which included range of very advanced subsonic commercial aircraft/engines that pushed to limits of “practical and feasible” technologies

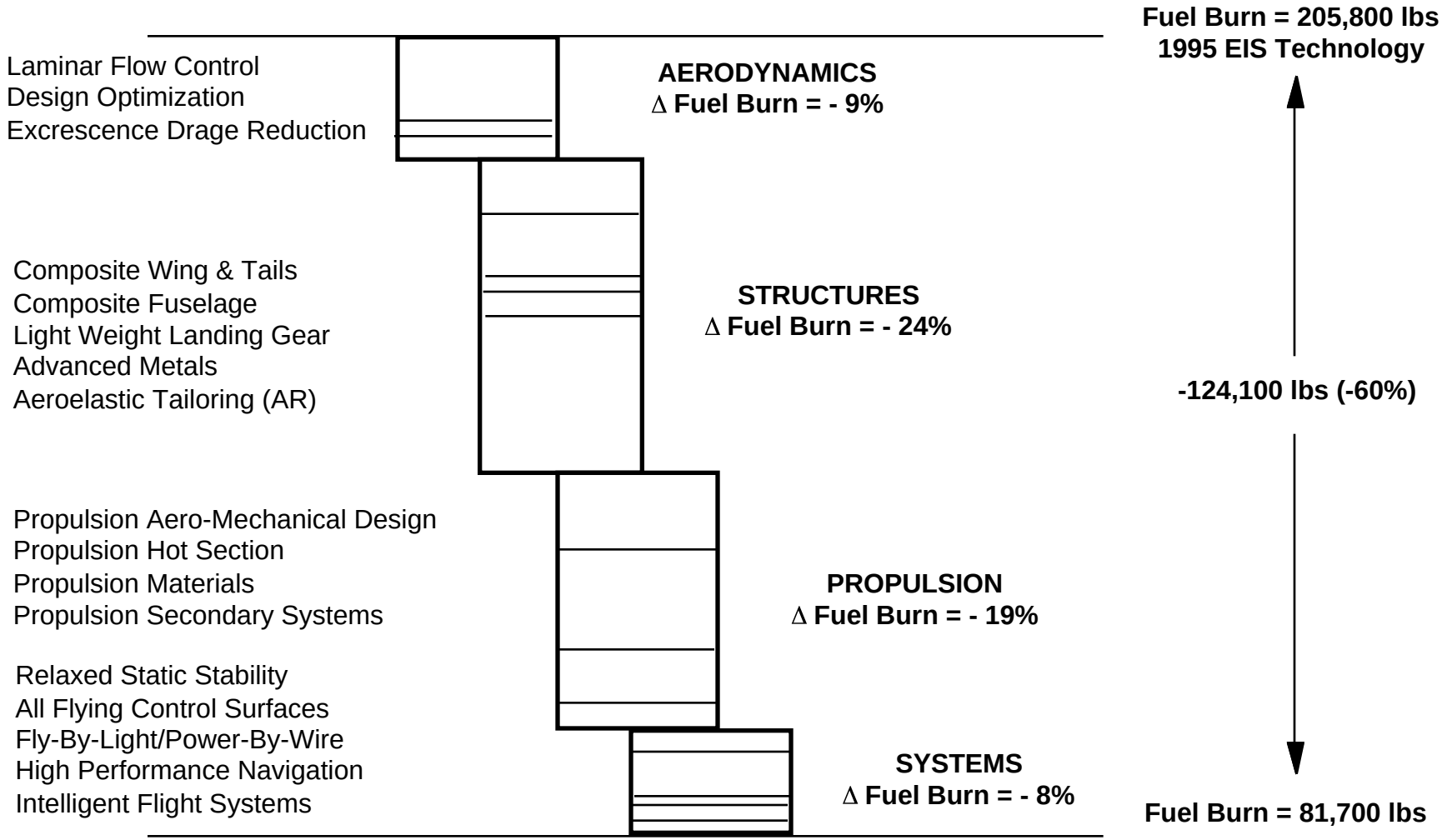
- Based on this study, 50 percent appears to be reasonable CO2 limiting reduction goal for the 2022 average of new hydrocarbon fueled aircraft that will range from 50 to 600 passenger.

- Based on knowledge of AST fueled burned benefits, an aggressive interim goal of a 25 percent reduction was selected for the ten year CO2 goal

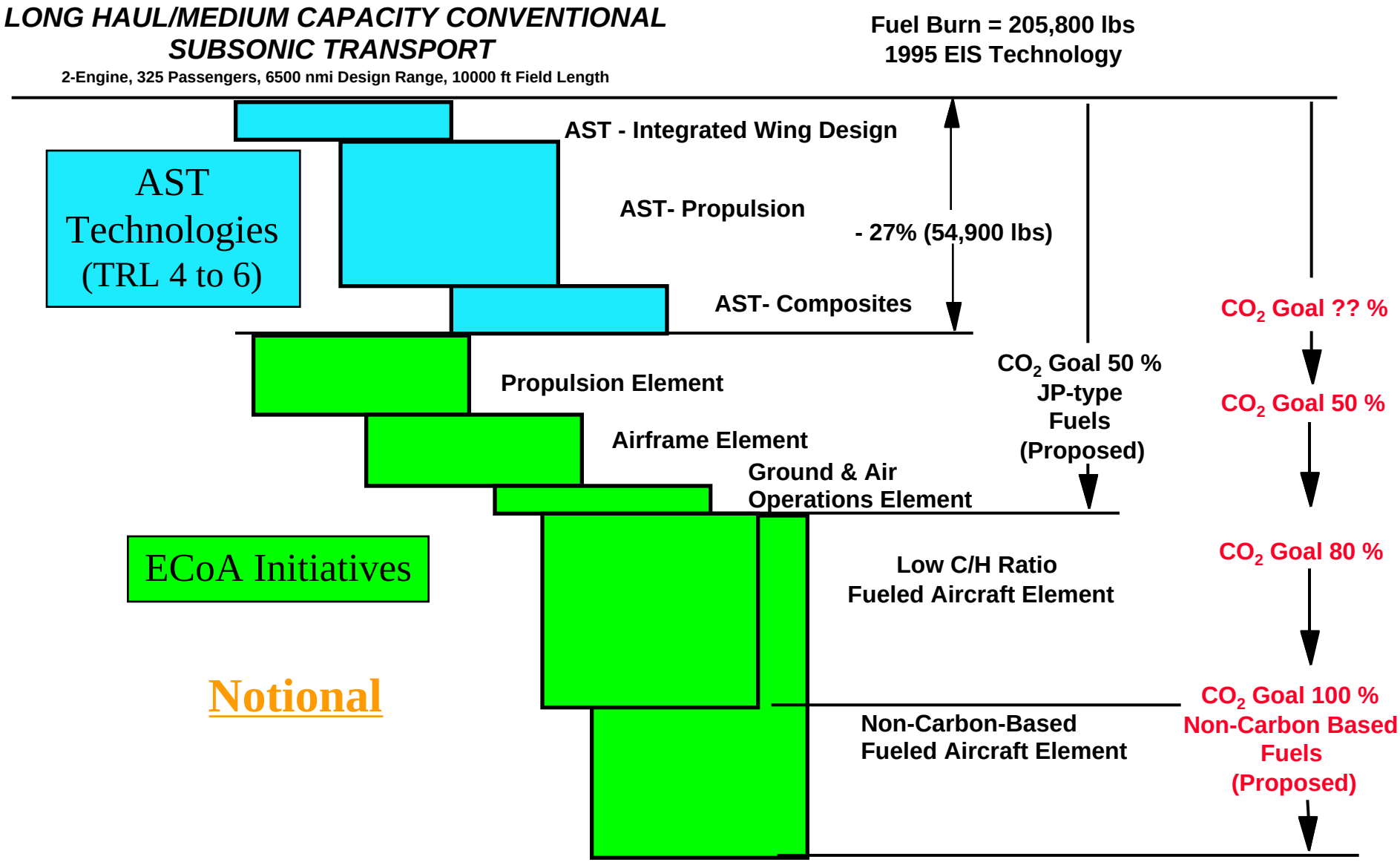
325 PAX CONVENTIONAL SUBSONIC TRANSPORT

2-Engine, 6500 nmi Design Range, 10000 ft Field Length

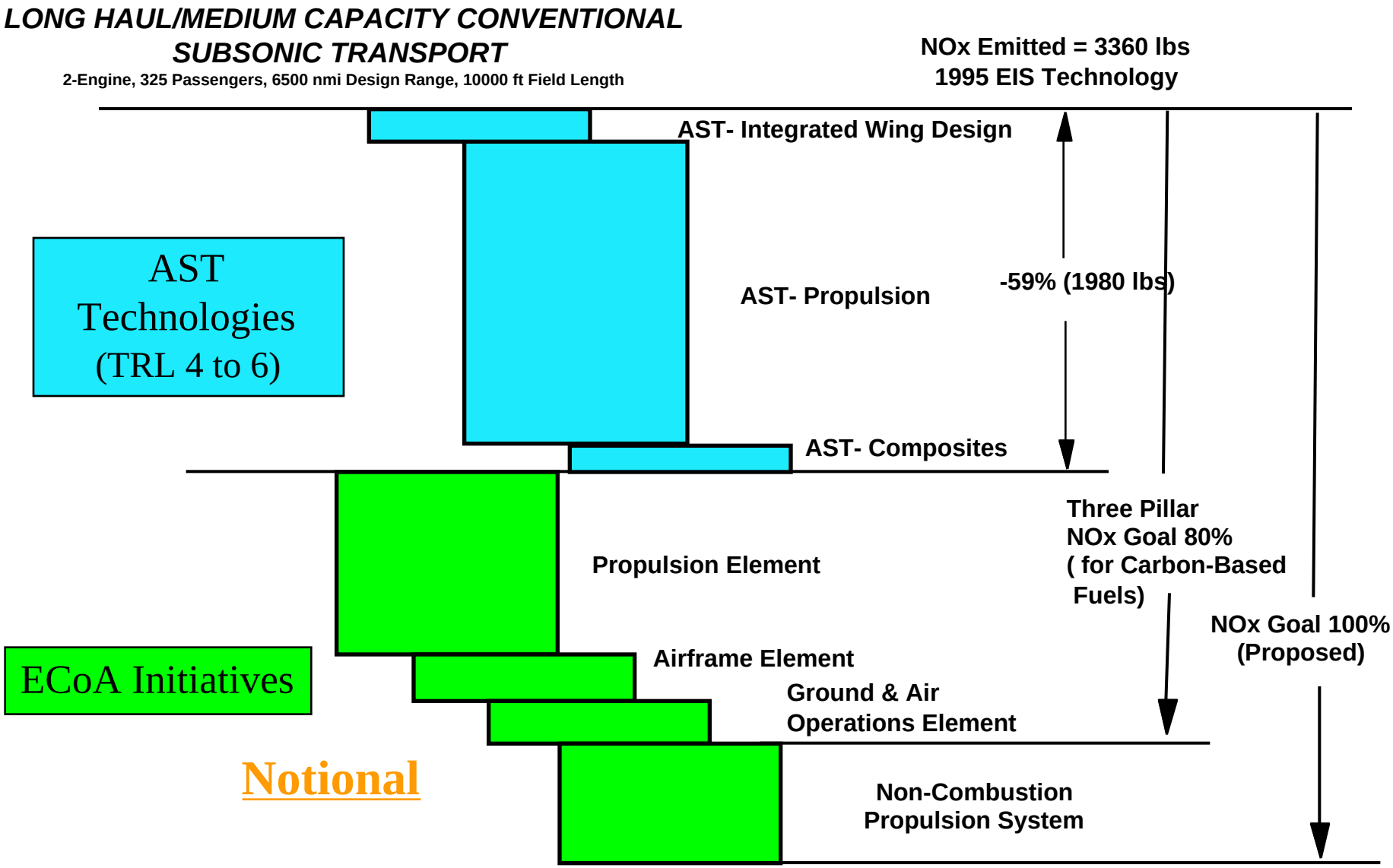
Fuel Burn "Waterfall" - Scenario-Based Vehicle Technologies



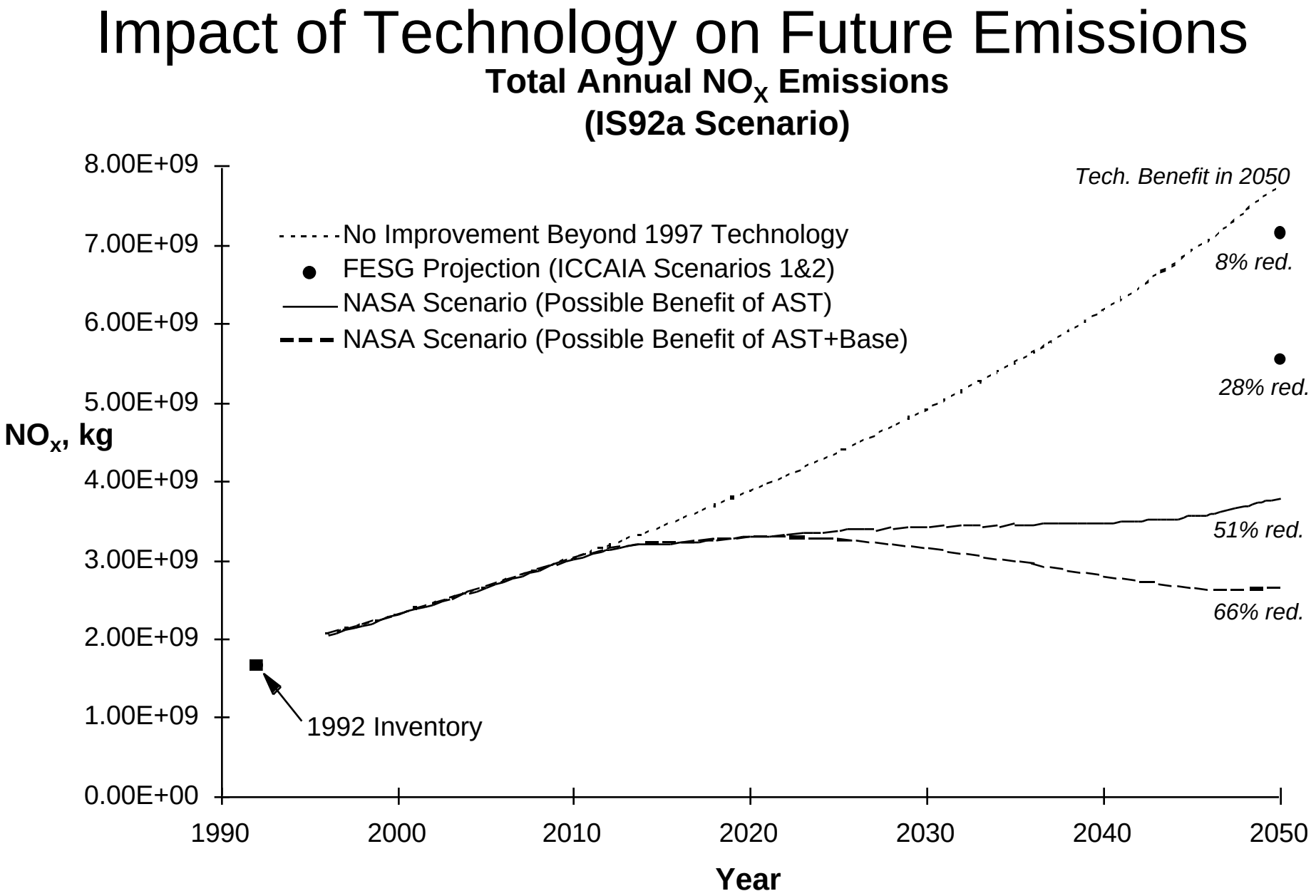
Environmental Program CO_2 Emission Reduction Waterfall



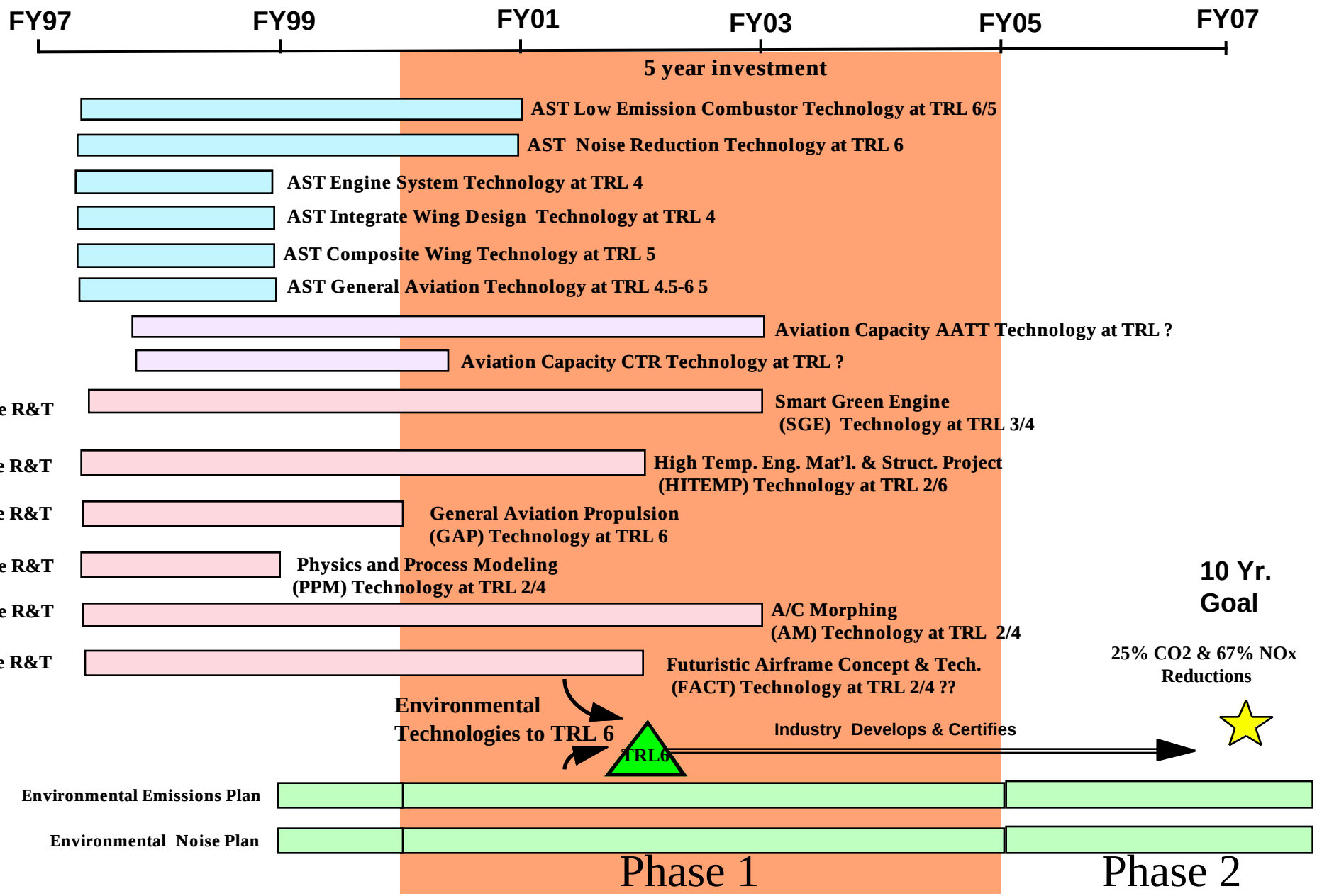
Environmental Program NOx Emission Reduction Waterfall



Impact of Technology on Future Emissions



Roadmap Of AST ,Aviation Capacity, & Base R&T Technology Benefits On **Subsonic Aircraft**



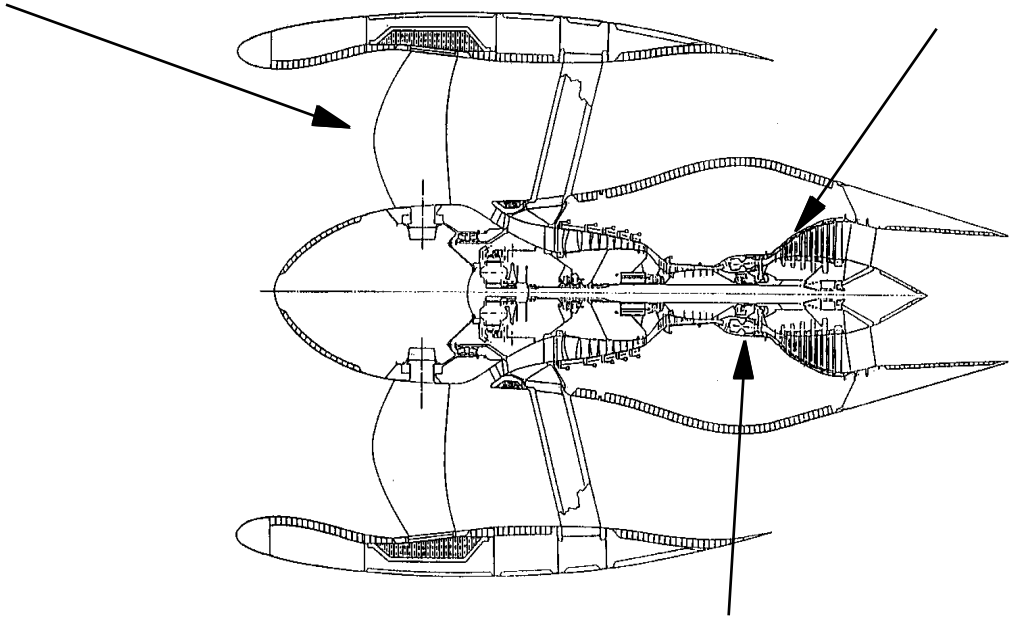
AST Engine Systems and Emission Reduction Elements

Advanced Subsonic Technology

Technologies required For 2005 Entry Into Service
AST Very High Bypass Engines

Higher Bypass Propulsor
- Improved low noise fan (part of Noise Element)
- Improved lightweight static structure materials & lifing TRL 6 ► 3
- Fan bypass duct optimization TRL 4 ► 3
- Improved lubrication and health and usage monitor for geared, very high-bypass engines TRL 4 ► 3

High Efficiency Core
- Improved turbomachinery aerodynamic, aeroelastic, & film cooling codes TRL 6 ► 4
- Improved High OPR materials with enhanced crack growth resistance TRL 5 ► 4
- Improved controls technology TRL 6 ► 4

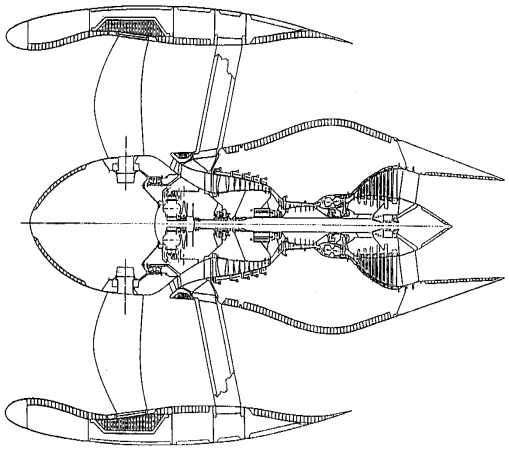


Reduced Emissions Combustor
- Compact high pressure and temperature combustor TRL 6 ► 6/5

AST Engine Systems Element

Major Deliverables / Products

- Improved engine design and development cycle time reductions of 30-40%, improved engine durability components and analyses, and improved reliability through controls and health monitoring systems
- High payoff propulsion technologies to enable future U.S. commercial engines with 3-10% reduction in average seat mile cost of air travel , 8 -10 % improvement in fuel efficiency for large and regional engines



- Three advanced compressor and turbine components and improved/validated aerodynamic turbomachinery codes or models/physics will be available for use in industry's design systems by 1999
- Demonstrate prototype manufacturing of extended life disk
- Lightweight, affordable composite components demonstrated
- Lubrication system and health monitoring system demonstrated for geared engines

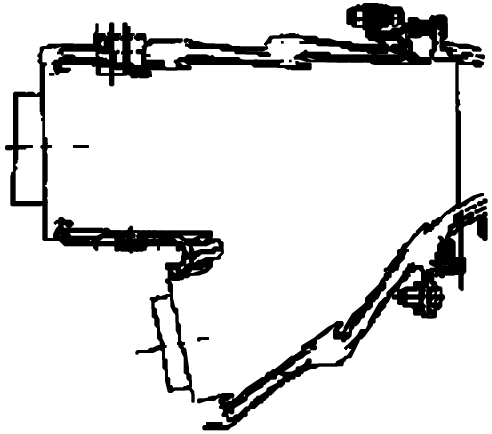
Customers: - U.S. Aeropropulsion and Airframe Manufacturers

- U.S. Airline Industry

AST Emission Reduction Element

Advanced Subsonic Technology

Major Deliverables / Products



TRL 6 - Phase 1
TRL 5 - Phase 2

Work with U.S. Industry to provide technology readiness to:

- Demonstrate by 1999 reductions in takeoff NOx emissions of at least 50% of the 1996 ICAO limits for future large and regional engine (50:1 & 30:1 Pr) combustors with corresponding reductions in cruise NOx levels, no increases in other emission constituents (CO, smoke, and Unburned hydrocarbons), and comparable operability and maintainability,

- Demonstrate by 2001 reductions in takeoff NOx emissions of at least 70% of the 1996 ICAO limits for future large and regional engine (50:1 & 30:1 Pr) combustors with corresponding reductions in cruise NOx levels, no increases in other emission constituents (CO, smoke, and Unburned hydrocarbons) and design methodology and databases to understand additional emission reductions of 70% lower NOx

- Address new emission concerns with effort to understand the emission levels of aerosols and particulates coming from low emission combustors.

Customers: - U.S. Aeropropulsion and Airframe Manufacturers

- U.S. Airline Industry

MAJOR DELIVERABLES/ PRODUCTS

- Integrated computational and experimental fluid dynamics for
  - 15 - percent reduction in aero design cycle time
- Validated tools that permit rapid design of multipoint wing including the effects of PAI and yield
  - 2 - percent decrease in cruise drag with 0.08 increase in buffet CL
  - elimination of one high-speed wind-tunnel test cycle
- Validated analysis tools that enable cost effective implementation of advanced low-noise, high-lift system concepts and yield
  - elimination of one low-speed wind-tunnel test cycle
- Validated mid-term progress against MSR's through conduct of system studies for baseline and baseline with IWD technology and design process advances

AST Airframe Materials & Structures

Stitched/RFI Wing Technology

25% Weight Reduction, 20% Cost Reduction

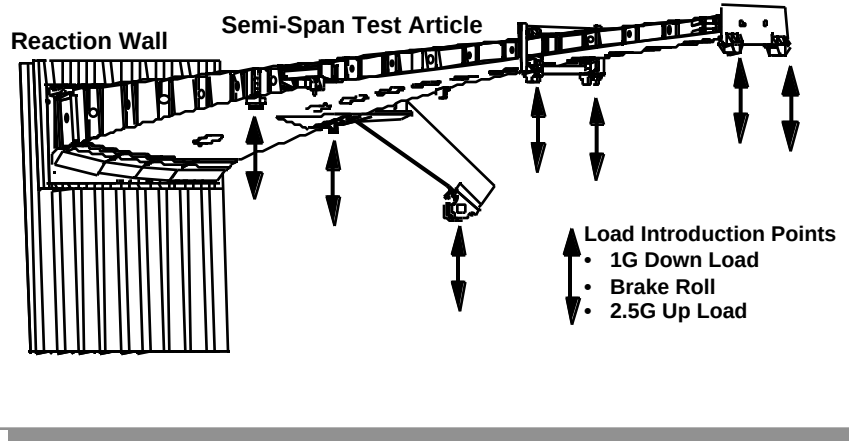
Cover Panel D

Design Concepts:
Completed

Marvin B. Dow Stitched Composites Development Center at Boeing, Huntington Beach, CA

Fabrication:
Advanced stitching machine operational, cover panels being fabricated

Test & Analysis:
Analysis underway, Semi-span test article for structural performance and weight validation, to be delivered and tested at LaRC, 6/99



Airframe Materials & Structures

Major Deliverables

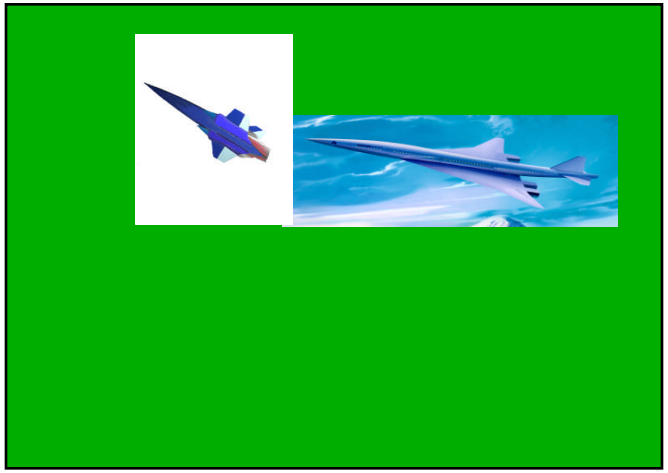
- Efficient, affordable composite wing designs for generic transports (Semi-Span Wide Body)
- Materials properties, fabrication processes, cost data
- Analytical models for predicting fabrication process parameters
- Analytical models for predicting structural response
- Verified ground test structural performance
- Data base and methodology to support FAA Certification

Advanced High Temperature Engine Materials Technology

Light Weight

High Temperature

Design Methods



Reduce Cost of Air Travel
Increase Safety
Reduce Emissions & Noise
Reduce Design Cycle Time
Reduce Cost to Orbit
Reduce Cost in Space

SMART GREEN ENGINE (SGE), 523-26

SGE aligned with ASTT Pillar One: GL

Primary Goal: ENVIRONMENT

REDUCE EMISSIONS thru Low Emissior

Secondary Goal: AFFORDABILITY

REDUCE COST thru Reduced Part Cour

REDUCE DESIGN CYCLE TIME thru Co

Emissions Testing - Particulates/Aerosols Charac.

Compressor Stability - Enhancement w/Tip Injection

Computation Analysis Tools for Multistage Turbomachinery

Topping Cycles - Wave Rotor Topped Demo